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TESTING WATER METERS IN SERIES[1]

By J. E. Garratt[2]

Will water meters show the same percentage of registration on test if tested singly or in series of two, three, five, ten or any number? Some will immediately say "No;" others will, perhaps, say, "Yes;" and some who say "Yes" might think they were wrong if it was left to a test to furnish the proof.

Meters are tested at different rates of flow, these different rates of flow being usually determined by orifices of different sizes. It is common practice for the meter testing man to refer to a test as "with a $\frac{1}{32}$-inch orifice" or "with a $\frac{1}{8}$-inch orifice" or any other size. He knows that a $\frac{1}{16}$-inch orifice allows more water to pass on the test in a given time than a $\frac{1}{32}$-inch orifice does and that a $\frac{1}{2}$-inch orifice passes more water than a $\frac{1}{4}$-inch, etc., but he considers that a certain size of orifice always gives the same amount of water through it in a given time. That is because he deals with a pressure in his particular city which is more or less steady and practically the same from day to day, but he forgets that that pressure of his may be 100 pounds per square inch while another city's may be only 40 pounds per square inch and the flows through orifices, of course, are different with different pressures, in fact they vary about as the square root of the pressure, so that if the pressure is doubled the rate of water passing through the same size of orifice is increased about one-half. Consequently, a $\frac{1}{16}$-inch orifice in one meter testing room may mean two times or three times or one-half or any number of times or any part of what it does in some other testing room, provided the amounts of water passed by the orifice are expressed as a rate of so many gallons or cubic feet or pounds of water per minute or any other unit of time.

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[1] Presented at the Montreal Convention, June 23, 1920. Discussions are invited and should be sent to the Editor.

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The first point, then, very evidently is that in all meter testing the various points at which the meters are tested should be designated as so many gallons or cubic feet or pounds per minute and not as at such and such an orifice.

If this is done and the same rates are produced when the meters are tested in series as when tested singly, the answer to the question which started this paper is "Yes, water meters will show the same percentage of registration on test whether tested singly or in series of any number."

The whole cause of the question in regard to this matter is due to this fact that the rates of flow, as already stated, are usually determined by orifices and the same orifices are used on the series test as on the single test, but the same orifices may not give the same rates of flow even in the same testing shop. Why? Because there may not be the same resulting pressure at the orifice.

When water passes through a meter at a certain rate there is a certain pressure loss in the meter which is different with different sizes and makes of meters. Also this pressure loss is different for different rates passing the meter and varies about as the square of the rate, that is, if the rate is doubled the pressure loss is about four times as great.

Now suppose a meter is tested by itself, using a $\frac{1}{8}$-inch orifice and a pressure of 70 pounds per square inch available at the inlet side of the meter. There are certain losses through the meter and piping, leaving a resulting pressure at the orifice of less than 70 pounds per square inch by the amount of the losses. The rate at which the meter is tested, is then, the flow through a $\frac{1}{8}$-inch orifice at this pressure of 70 pounds less the losses.

Now suppose four meters are tested in series. The total loss through the four meters is about four times what it was through the one. Consequently the pressure at the orifice is less than on the single test by about three times the loss through one meter. Consequently the pressure at the orifice is less than before and since the amount of water passed by the orifice depends upon the pressure, the rate of flow at which the meter is tested will be less although the same orifice is used in each test. Such being the case, the two tests with the same orifice may not show the same percentage of registration because they are at different rates of flow.

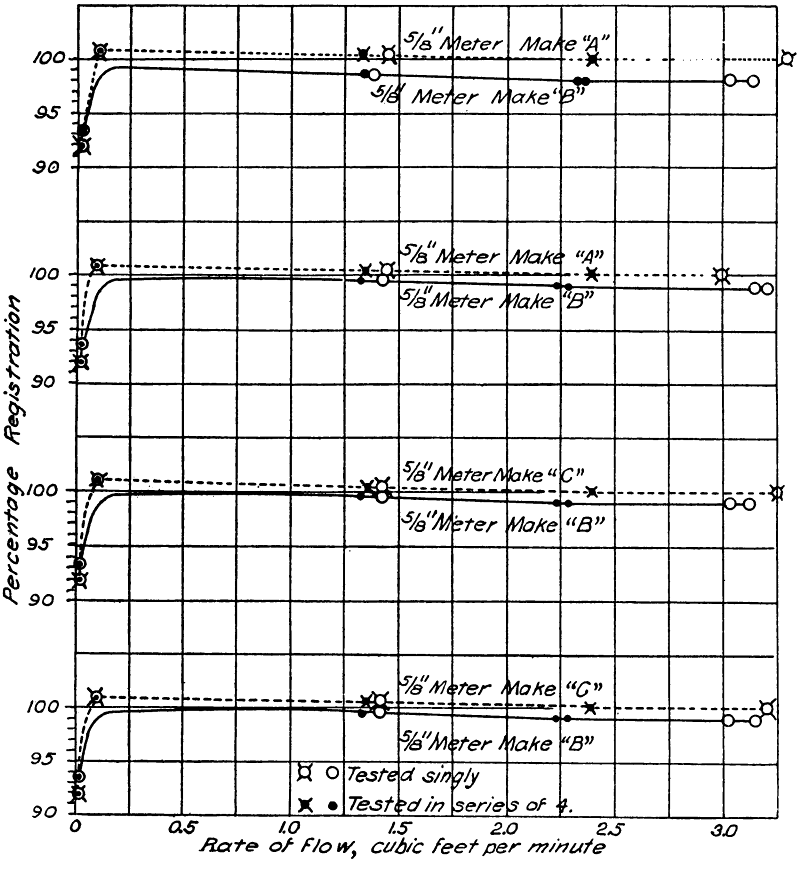

FIG. 1. CURVES SHOWING THAT RESULTS OF ACCURACY TESTS OF METERS ARE THE SAME WHEN TESTED SINGLY OR IN SERIES

Actually, it works out that way in water works meter testing only in exceptional cases, where many meters are tested together or where extreme refinements of test are carried through. This is due to the form of the meter registration curve of test, as shown in figure 1. This curve rises quickly at a very low rate of flow to a few per cent below or above 100 and holds there with slight variation throughout the rest of its run. Tests with very small orifices which would lie in the rapidly rising low range of the curve produce practically the same rates of flow because at low rates of flow the losses in the meters are very small so that the difference in the resulting pressure at the orifice is very small and therefore the rates of flow are, for all practical purposes, the same and the percentages of registration are the same. With larger orifices producing greater rates of flow, the losses in the meters are larger and become appreciable so that the resulting pressures at the orifices are different by the two methods of test and consequently the rates of flow through the meters are different. But the curve of registration usually varies so little and so gradually from the 100 per cent line, or a line parallel to the 100 per cent line, that the different rates of flow on the two tests are not so far different as to show different percentages of registration. This is very plainly shown in figure 1 and in table 1.

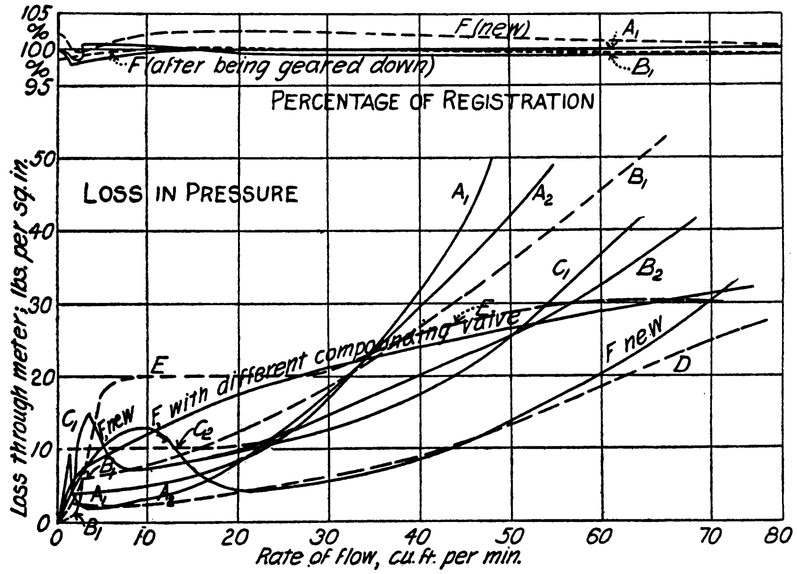

Fig. 2. Loss in Pressure Through 3-Inch Compound Meters of Various Makes

Of course the greater the number of meters tested in series as compared with the single test the greater the losses through the meters, the greater the difference in the resulting pressures at the orifice and the greater the difference in the rates of flow. The greater this difference in rate of flow, the greater the likelihood of different percentages of registration.

TABLE 1

Percentage registration of meters tested singly and in series of four meters

METER	ORIFICE	TESTED SINGLY		TESTED IN SERIES	
		Rate	Registration	Rate	Registration
	inch	*cu. ft./min.*	*per cent*	*cu. ft./min.*	*per cent*
A	$\frac{1}{2}$	3.03	99.1	2.24	99.0
	$\frac{1}{4}$	1.42	99.7	1.32	99.7
	$\frac{1}{32}$	0.024	93.3	0.021	93.3
A	$\frac{1}{2}$	3.03	99.1	2.24	99.0
	$\frac{1}{4}$	1.43	99.7	1.32	99.7
	$\frac{1}{32}$	0.024	93.3	0.021	93.3
B	$\frac{1}{2}$	3.30	100.0	2.40	100.0
	$\frac{1}{4}$	1.45	100.5	1.36	100.5
	$\frac{1}{16}$	0.10	100.8	0.10	100.8
	$\frac{1}{32}$	0.024	91.9	0.021	91.9
C	$\frac{1}{2}$	3.28	100.0	2.40	100.0
	$\frac{1}{4}$	1.42	100.5	1.36	100.5
	$\frac{1}{16}$	0.10	100.8	0.10	100.8
	$\frac{1}{32}$	0.022	91.9	0.022	91.9

The one conclusion to be drawn from this discussion is that all tests of meters should be referred to rates of flow through the meter in cubic feet or gallons or pounds per minute or hour and not to size of orifice. If this is done it makes no difference whether meters are tested singly or in tandem or in series of ten or of one hundred, the percentage of registration will always be the same at the same rate provided the mechanical condition of the meter has not changed.